Impact of Non-Idealities System on Spatial Correlation in a Multi-Probe Based MIMO OTA Setup

Fan, Wei; Nielsen, Jesper Ødum; Carreño, Xavier; Jagjit, Jagjit; Pedersen, Gert Frølund; Knudsen, Mikael

Published in:
Proc. 7th European Conference on Antenna and Propagation (EUCAP 2013)

Publication date:
2013

Document Version
Early version, also known as pre-print

Impact of Non-Ideal System on Spatial Correlation in a Multi-Probe Based MIMO OTA Setup

Wei Fan, Jesper Ø. Nielsen, Xavier Carreño, Jagjit S. Ashta, Gert F. Pedersen and Mikael B. Knudsen

I. Introduction

As a promising solution to evaluate MIMO device performance in realistic situations, MIMO over the air (OTA) testing has attracted huge interest from both industry and academia [1]. Standardization work for the development of the MIMO OTA test methods is ongoing in CTIA, 3GPP and COST IC1004. The main challenge as we move from SISO OTA to MIMO OTA testing lies in what is new and critical, i.e. on the spatial characteristics of the channel.

The multi-probe anechoic method has been an important candidate for OTA testing. With this method, multipath environments in which the performance of the device is evaluated can be physically emulated in a controllable manner[3].

For the multi-probe based method, the objective is with a limited number of probes to generate an arbitrary number of clusters with associated arbitrary Angle of Arrivals (AoAs) and Azimuth Spreads (ASs) in the target area. Methods addressing this issue has been reported in [2], [3] and [4]. It has been shown that the essence is to find proper power weightings for each probe such that channel spatial characteristics can be recreated. Spatial correlation has been selected as the main figure of merit to characterize the channel spatial information. The mentioned works have been focused on how to obtain power weights from a theoretical point of view. However, the power weights can be effectively distorted due to the non-idealities in a practical setup.

In [6], channel validation measurements have been considered necessary for various OTA methods to ensure that the channel models that we are targeting for are correctly implemented. The target channel models considered for evaluation of MIMO OTA performance in [6] are SCME Urban microcell (UMi) tap delay line (TDL) model, SCME urban macrocell(UMa) TDL model, SCME UMi single cluster model and SCME UMa single cluster model. This paper presents the spatial correlation measurements for the four target channels. The focus is on investigation on the deviations between target, simulations and measurements in a practical setup. Spatial correlation is a figure dependent on the spatial properties of the channel. In a practical setup, power variation over frequency will effectively distort the power weights allocated to probes and deteriorate channel emulation accuracy. Power calibration of the MIMO OTA setup is generally performed at a single frequency and calibration values are not constant over certain bandwidth (e.g. 10MHz). Possible factors that introduces power variation over frequency and their impact on channel emulation are investigated in this paper.

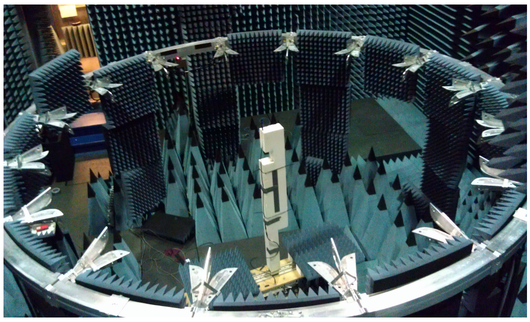

Figure 1. Practical anechoic chamber setup in the measurement system

II. Measurement system

A. Configuration of MIMO OTA setup

Figure 1 shows the practical anechoic chamber setup in the measurement system. 16 dual polarized horn antennas are equally spaced and fixed on a aluminium OTA ring with radius 2m. The OTA ring is covered by absorbers to alleviate reflections during the test. The measurements and study in this work are carried out in LTE band 13 with center frequency 751MHz in downlink.

B. Spatial correlation measurement

Spatial correlation measurement details are specified in [6]. Measurements were performed over 11 test antenna positions with step of 0.1λ. For each measurement at each position, 1601 samples are obtained over 10MHz bandwidth with frequency resolution 6.25 KHz. [1]

III. Methods

The antenna pattern is generally assumed to be omnidirectional for channel emulation purpose. The target spatial correlation is calculated as:

$$\rho = \int_{-\pi}^{\pi} \exp(-j2\pi \frac{d}{\lambda} \sin(\phi)) PAS(\phi) d\phi \tag{1}$$

where PAS is the target power azimuth spectrum distribution of the clusters and d is the antenna separation between the two antennas.

The emulated spatial correlation can be calculated as:

$$\widetilde{\rho} = \sum_{k=1}^{K} P_k \cdot \exp(-j2\pi \frac{d}{\lambda} \sin(\theta_k)) \tag{2}$$

[1]Detailed description of the measurement will be included in the final paper.

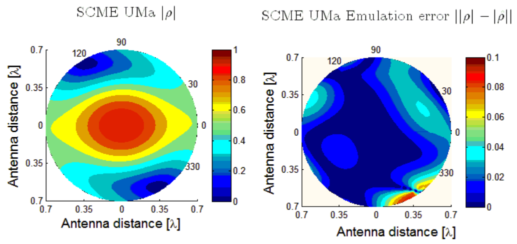

Figure 2. Target spatial correlation $|\rho|$, emulation error $||\rho|-|\hat{\rho}||$ versus the normalized distance and antenna orientation for SCME UMA TDL model

where P_k and θ_k are the power weights and angular location for the kth probe, respectively. Optimization techniques to obtain the power weights $P = \{P_k\}$ for a given probe configuration have been detailed in [3] and [4]. The target spatial correlation for SCME UMa TDL and the emulation error with 8 probes for a test zone with radius 0.7λ are illustrated in Figure 2. The radius and polar angle of each point on the plots correspond to the value at the normalized distance d and antenna orientation. Simulation coincides quite well with theoretical spatial correlation with 0.7λ antenna separation. The deviation between target and emulation is due to the limited number of probes used for channel emulation. The more probes we use, the smaller deviation we should expect.

In case the power levels are dependent on frequency, the emulated spatial correlation will be modified according to

$$\widetilde{\rho}(f) = \sum_{k=1}^{K} \bar{P}_k(f) \cdot \exp(-j2\pi \frac{d}{\lambda} \sin(\theta_k)) \tag{3}$$

$$\bar{P}_k(f) = P_k \cdot \frac{C_k(f)}{C_k(f_c)} \tag{4}$$

where f_c is the calibration frequency. $\frac{C_k(f)}{C_k(f_c)}$ denotes the power variation level at frequency f for probe k. Figure 3 illustrates the measured power variation over 10MHz bandwidth. The calibration was performed at center frequency 751MHz. The power variation are mainly due to the cable reflection and power drifting over frequency at channel emulator and power amplifiers. The impact of power variation over frequency on spatial correlation is shown in Figure 3 as error bars.

IV. Results

Figure 4 shows examples of measurement results to be discussed in detail in the full paper. The variation of spatial correlation over 10MHz bandwidth is shown in Figure 4 as error bars.

V. Conclusion

Due to system non-idealities in a practical setup, i.e. power drifting over frequency at channel emulator and power amplifier, physical limitation of the setup, reflections in the cables and reflections inside the chamber, spatial correlation over a 10MHz bandwidth is with a variation up to 0.15 in the UMi TDL and the UMa TDL scenarios. Variations of up to 0.25 can be found in the UMi single cluster and the UMa single cluster scenario. Sources of non-idealities in the system is investigated. Techniques to alleviate the impact of system non-idealities will also be presented.

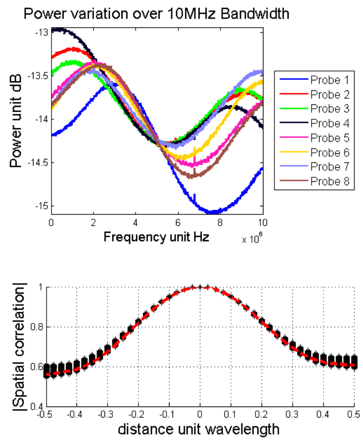

Figure 3. Power variation over 10MHz (up) and emulated spatial correlation for SCME UMa TDL scenario considering power variation over frequency. The red line represents the spatial correlation at the calibrated frequency.

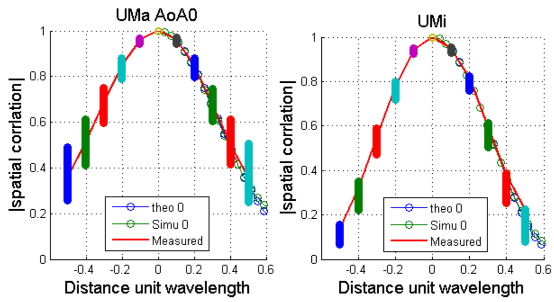

Figure 4. The comparison between emulated, measured and theoretical spatial correlation curves at orientation 0 for UMa single cluster and SCME UMi TDL.

References

[1] David A. Sanchez-Hernandez, Moray Rumney, Ryan J. Pirkl, and Markus Herrmann Landmann. MIMO Over-The-Air Research, Development, and Testing. Hindawi Journal of Antenna and Propagation. 9 May 2012.

[2] Matt A. Mow, Bo Niu, Robert W. Schlub, Ruben Caballero, inventor; 2011 Nov. 3. TOOLS FOR DESIGN AND ANALYSIS OF OVER-THE-AIR TEST SYSTEMS WITH CHANNEL MODEL EMULATION CAPABILITIES. United States patent US 2011/0270567.

[3] Pekka Kyösti, Tommi Jämsä, and Jukka-Pekka Nuutinen, "Channel Modelling for Multiprobe Over-the-Air MIMO Testing," International Journal of Antennas and Propagation, vol. 2012, Article ID 615954, 11 pages, 2012. doi:10.1155/2012/615954.

[4] John Douglas Reed, inventor; 2011 Dec. 8. EMULATION AND CONTROLLED TESTING OF MIMO OTA CHANNELS. United States patent US 2011/0299570.

[5] P. Kyösti, L. Hentilä, "Criteria for Physical Dimensions of MIMO OTA Multi-Probe Test Setup," EuCAP 2012, Conference Paper.

[6] 3GPP TR 37.977 , "Verification of radiated multi-antenna reception performance of User Equipment (UE)," Release 11, Technical Report, 2012.